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BOARD ON MATHEMATICAL SCIENCES
NATIONAL RESEARCH COUNCIL

FINAL REPORT

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BOARD ON MATHEMATICAL SCIENCES
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES
NATIONAL RESEARCH COUNCIL
WASHINGTON, DC

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BOARD ON MATHEMATICAL SCIENCES

BACKGROUND

The National Research Council (NRC) established the Board on Mathematical Sciences (BMS) in December 1984 to oversee activities formerly conducted by the Office of Mathematics and the Committee on Applied and Theoretical Statistics (CATS). The Board consists of 15 members: the chair, and representatives of core mathematics (4), applied mathematics (4), the statistical sciences (3), operations research (1), and cross-disciplinary areas of research in bio-medicine (1) and the social sciences (1). The Board added these latter three seats in 1988 to broaden its representation of the mathematical sciences and to facilitate studies with other fields. The Board has one standing committee, the Committee on Applied and Theoretical Statistics (CATS). CATS predates the Board and has a history of involvement with scientific reports and issues affecting the statistical sciences and the use of statistics. During its short tenure, the Board has created or absorbed standing advisory panels to the Office of Naval Research, the Air Force Office of Scientific Research, and the National Security Agency, and established and provides direction to a major project to assess collegiate mathematics. Additional committees and panels are formed as needed to carry out individual projects. The Board, CATS, and the advisory panels comprise over 100 mathematical and other scientists, including many members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

During its last year of operation (1984), the former NRC Office of Mathematics completed work on two major reports. The first report, Renewing U.S. Mathematics: Critical Resource for the Future, written for the federal agencies, is perhaps the most significant report on issues affecting the mathematical sciences. This report, known best as the David Report, after former Presidential Science Advisor Edward E. David who chaired the report committee (the Committee on Resources for the Mathematical Sciences), assessed the state of funding support for mathematical science, recommended a five-year plan for renewal, and gave rise to positive change. Creation of the Board on Mathematical Sciences came in response to the deliberations and developing recommendations of the David Committee. The second report, Computational Modeling and Mathematics Applied to Physical Sciences, was completed in 1984 by the standing Committee on Applications of Mathematics (CAM). The Board distributed copies of these reports to ICEMAP federal agencies and widely within the mathematical sciences community.

The program of the Board on Mathematical Sciences is designed primarily: (1) to undertake studies and produce reports, assessments and recommendations involving core mathematics, applied mathematics, statistical science, operations research, and applications, and (2) to maintain an active presence at the NRC for the mathematical sciences. Among the functions of the Board on Mathematical Sciences are to:

- serve as the focal point at the NRC for issues involving and affecting the mathematical sciences and provide support for related NRC efforts in computer science and mathematical sciences

education;

- identify new and critical issues in the field, including issues involving talent flow and graduate education;
- keep abreast of research developments and trends in mathematical science and provide a forum and mechanisms to communicate this information to the ICEMAP agencies, the mathematical sciences community, and other sciences and engineering;
- develop new studies and respond to requests for studies from federal agencies in areas including research, training, talent, trends, applications, and infrastructure issues;
- assure prompt and effective response to problems regarding the basic knowledge and capabilities of the mathematical sciences;
- ensure representation and participation of U.S. mathematical science in international programs and research projects through supervision of the U.S. National Committee for Mathematics (USNCM) and the U.S. Commission on Mathematical Instruction (USCMI);
- maintain awareness of developments in the mathematical sciences and their interfaces with other disciplines, and ensure the effective communication of these developments to stimulate research and enhance awareness of the role of mathematical science in modern science, technology, and commerce;
- maintain liaison with mathematical sciences communities in academia, government agencies and laboratories, industry, and with appropriate professional societies;
- provide supervision, administrative support, and financial oversight to NRC committees, panels, and projects in relevant areas, recommend individuals to serve on these groups, and coordinate membership and activities across projects and groups;
- recommend individuals with outstanding expertise in specific mathematical science research and policy areas to participate in NRC and other studies.

Accomplishments: 1986 - 1987

An important function of the Board is to provide the capability to produce state-of-the-art reports and reviews by enlisting the services of the most knowledgeable experts available on a pro bono basis. One such review, Mathematical Sciences: A Unifying and Dynamic Resource, released in 1986 by the Board's Panel on Mathematical Sciences, described major trends in mathematics. The report, through examples, illustrated its

assertions that mathematical discovery is in a changing period and that mathematics is the fundamental discipline of science and hence a critical U.S. resource.

In 1986, the Board sponsored the first of what has become an annual series of symposia in conjunction with National Science and Technology Week. The 1986 symposium, "Mathematics: The Unifying Thread in Science," focused on the interplay between mathematics and significant scientific achievements, and featured Nobel Laureates in chemistry, physics, and medicine, who spoke to the importance of mathematical science in their work and their field. In April 1987, the second symposium, "Statistics in Science, Industry, and Public Policy," was held focusing on the statistical sciences. Each symposium was attended by approximately 150 persons concerned with scientific and policy issues in mathematical science, and was followed by a dinner designed to facilitate dialogue between scientists and policy makers representing different important points of view. These symposia are an outgrowth of one of the recommendations set forth in the David Report--educating the public and policy makers about the importance of mathematical science in scientific and technological advancement. The symposia are designed to encapsulate areas of mathematical science of current interest and provide an opportunity for ICEMAP representatives and other concerned parties to meet and discuss topics of mutual interest and concern.

During this period, the Board, in cooperation with the NRC Mathematical Sciences Education Board (MSEB), began a comprehensive study of university mathematics concerns, "Mathematical Sciences in the Year 2000: Assessment for Renewal in U.S. Colleges and Universities," often referred to as the MS 2000 Project. The study investigates the status of mathematical science in U.S. colleges and universities and provides a framework for renewal by the year 2000, including: analysis of data to provide a national assessment of needs, resources, and opportunities, including minorities and women, in collegiate mathematical science; articulation of standards for curricula, faculty, resources, quality, and productivity of collegiate mathematical science departments and faculty; and recommendations for action by various organizations responsible for higher education including colleges and universities, federal agencies, state governments, foundations, and professional societies. The key concern of the Board on Mathematical Sciences here is that of ensuring the development and training of U.S. mathematical science researchers, educators, and practitioners, and the mathematical and statistical training of U.S. scientists and engineers, both qualitatively and quantitatively.

In October 1987, preparatory to the MS 2000 project, BMS and MSEB cosponsored a major colloquium, "Calculus for a New Century," at the National Academy of Sciences. Approximately 700 individuals were in attendance, and full proceedings were distributed in early 1988. The important facts that "calculus is big and calculus is in trouble" and that "calculus should be a pump, not a filter to science and engineering education, particularly for women and minorities" were established, and planning for renewal and improvement begun.

Each October in Washington, DC, the Board organizes and sponsors a two-day colloquium for mathematical sciences department chairs and other concerned parties, the Annual Department Chairs' Colloquium. The colloquia focus on areas of current interest and concern, such as progress on the recommendations of the David Report, the development of the MS 2000 project and issues in undergraduate education, use and access to computing resources for research, and new programs such as university research initiatives and science and technology centers. Each colloquium program includes one or more sessions organized by the Interagency Committee for Extramural Mathematics Program (ICEMAP) to facilitate information flow between department chairs and funders of mathematical science research. Luncheons are organized around discussion groups led by ICEMAP agency representatives. The result has been a series of colloquia that provides a unique, efficient, and cost-effective means for ICEMAP to strengthen working relationships with the full set of mathematical science research department chairs and to provide and receive important information.

In 1986, the U.S. Commission on Mathematical Instruction organized introductory sessions of a tutorial nature to the International Congress of Mathematicians (ICM) in Berkeley, California. The U.S. National Committee for Mathematics represents the U.S. mathematical community in the International Mathematical Union, and is responsible to assure adequate U.S. representation at ICMs. As a result of a travel grant program sponsored by the USNCM and funded by NSF, approximately 50 young researchers in mathematics were awarded grants to attend ICM-86. This was a unique opportunity for these new researchers who had not yet received support (postdoctoral or regular) for travel and are no longer graduate students.

The Committee on Applied and Theoretical Statistics has maintained an active presence at the NRC and concern for the statistical sciences for many years. In 1986, CATS issued a report on the recommendations of its Panel on Evaluation of Statistical Software. This Panel reported on its recommendations in a broad area of questions involving scientific computing related to statistics. These recommendations were reported to the Computer Science Division at NSF. CATS organized and supervised the work of two separately funded panels to investigate the state of knowledge and research in the areas of nonstandard mixtures of distributions and discriminant analysis, classification, and clustering, leading to two subsequent NRC state-of-the-art reports, Statistical Models and Analysis in Auditing and Discriminant Analysis and Clustering.

During 1987, the Board's other two standing committees, the Committee on Mathematics and the Committee on Applications of Mathematics were dissolved in favor of the work of other Board panels and projects and coordination of development of the Board's major scientific report, Mathematical Sciences: Some Research Trends. With NRC approval, the Board may establish or reestablish any committee it deems worthwhile.

During 1986-87, the Board supervised the work of three advisory panels to federal agencies, two of which were created during this period. The Panel on Applied Mathematics Research Alternatives for the Navy (PAMRAN),

formed in 1977, provides expert advice to the mathematical sciences program at the Office of Naval Research (ONR), and, through ONR, to naval research laboratories and programs. The Advisory Panel to the Mathematical and Information Sciences Directorate, Air Force Office of Scientific Research (AFOSR), provided similar services to the Air Force. PAMRAN issued an advisory report in 1987, Selected Opportunities for Mathematical Sciences Research Related to the Navy Mission. The AFOSR Panel issued Report of the Advisory Panel to the Mathematical and Information Sciences Directorate also in 1987. These reports play an important role in planning at these agencies. The Advisory Panel to the Mathematical Sciences Program of the National Security Agency (NSA) was formed in 1987. In addition to advisory services, this panel provides expert peer review for NSA's unclassified mathematical sciences research funding program. During the first semiannual round of proposal submission in 1987, the NSA Panel reviewed 86 proposals, 32 of which were funded during 1988.

The Board's role to organize, support, and supervise the work of its panels and CATS is an important one. The NRC is organized primarily around discipline-specific boards comprising panels and projects. The mathematical sciences, diverse in its organization, is well-suited to this structure. The Board coordinates the work and rosters of its committees and panels, and provides the locus for discussion and recommendations to the NRC Chairman regarding nomination and reappointment of members and the need to form new committees and panels and dissolve others, and the objectives and costs of such decisions. The Board supervises, organizes, and supports over 25 meetings of the Board and its committees and panels, symposia, and colloquia each year. These activities and their coordination by the Board are an important service to the mathematical sciences community and its research enterprise.

Accomplishments: 1988

The Board released a major scientific report, Mathematical Sciences: Some Research Trends in 1988. This report was identified as an important Board objective by the ICEMAP agencies in 1985 when ICEMAP first provided Board core support. The report describes important trends in core mathematics, applied mathematics, and statistical sciences. It includes vignettes which present in detail recent exciting developments in mathematical sciences research in each of eight specific areas. The report has been distributed widely among the federal agencies, university, government and industry research departments, science policy makers and professional societies. This report illustrates how the Board is positioned to attract the volunteer efforts of the most senior mathematical and other scientists to survey broadly the state and directions of research and applications.

CATS released two state-of-the-art research reports, Statistical Models and Analysis in Auditing and Discriminant Analysis and Clustering. The Audit report has received considerable attention in the accounting community as it met a longstanding need for sound statistical principles

upon which to base accounting practices. Many existing auditing practices are believed to be overly conservative, owing to the lack of statistical foundation. This report speaks well for the practical utility of statistical science research. Distribution was made to federal agencies, university statistics departments, professional societies, and selected accountants and researchers. The journal, Statistical Science, of the Institute of Mathematical Statistics devoted the February 1989 issue to reproduce the reports.

Under Board supervision, the proceedings of the 1987 colloquium, "Calculus for a New Century," of the MS 2000 Project and a PAMRAN report on seismic acoustic detection were released. PAMRAN began meeting at naval research laboratories to share more broadly its expertise with navy researchers and to gain a deeper understanding of problems of greatest importance to the Navy. The NSA Panel carried out a complete peer review including funding recommendations to NSA for 126 proposals during 1988.

The annual Department Chairs' Colloquium, was held October 14-15, 1988 in Washington, DC. The theme of the 1988 colloquium was "Computers in Mathematical Sciences Research and Training." The colloquium offered sessions on computation and computational algorithms, computer graphics and supercomputers in mathematical sciences research, and a session on computers in the classroom. There were also sessions on important policy issues, an ICEMAP roundtable, ICEMAP luncheon discussion tables, and a special workshop organized in cooperation with ICEMAP on methods for organizing and funding mathematical sciences research beyond the individual investigator model, including discussion of science and technology centers, special years, and equipment grants. This annual colloquium has developed into a unique and important opportunity for department chairs and ICEMAP agency representatives to work, plan, and become better acquainted and informed. The conference drew over 200 department chairs and representatives.

The U.S. Commission on Mathematical Instruction nominated the U.S. delegation to the International Congress on Mathematics Education in Budapest. The U.S. National Committee for Mathematics nominated the U.S. delegation to a summer session on operator algebras in Romania. On March 14, 1988, with the MSEB, the Board sponsored the preview of the NOVA public television film, "The Man Who Loved Numbers," based on the life of the Indian mathematician Srinivasa Ramanujan at the National Academy of Sciences (NAS) in Washington, DC. NAS President Frank Press hosted the affair, which was attended by 125 persons including the Science Advisor to the President and the Ambassador of India. NOVA asked the NAS and the Board to organize this preview.

On April 28, 1988, the annual Board on Mathematical Sciences symposium commemorating National Science and Technology Week was held. This year, the symposium also commemorated National Mathematics Awareness Week and was one of ten events throughout 1988 which celebrated the 100th anniversary of the American Mathematical Society. The symposium, "The Impact of Mathematics: Nonlinear Mathematics, Chaos, and Fractals in Science," focused on cross-disciplinary uses of mathematical sciences

theory and illustrated how rapidly the time between the development of this theory and its use in science and engineering research is decreasing.

Significant activities of an organizational nature took place in 1988. The Board expanded its membership to include representatives of operations research, biomedical mathematical science, and social sciences mathematical science, and created a four-member Executive Committee of the Board to facilitate and expedite planning and supervision of Board and committee activities. A Board liaison was assigned to the Mathematical Sciences Education Board (MSEB). Working with the MSEB and the MS 2000 staff, the Board on Mathematical Sciences secured funding and officially launched the MS 2000 project, which held a workshop on talent flow issues, formed and participated in two meetings and the work of a multi-disciplinary MS 2000 Oversight Committee, and participated in the development of the first Report to the Nation, released in 1989. This report summarized the problems in mathematical sciences education in the schools, colleges, and universities, leading to a focused agenda for MS 2000 and other activities.

Accomplishments: 1989

The Board has begun the development of a series of expository reports on cross-disciplinary research opportunities in mathematics and statistics. The David Report based its arguments for enhanced federal funding for mathematical sciences on the need to gain parity with other disciplines. To increase funding significantly, federal agencies must make arguments on sound scientific grounds. With the healthy and intense research activity in mathematical sciences, this can be done and these studies will aid that process by identifying and outlining areas that are ripe for cross-disciplinary research and enhanced funding. The reports will not make specific recommendations, but instead will describe the opportunities and potential inherent in the cross-disciplinary areas under study. The reports will be written for a general science and science policy audience, the first half introducing the field of application and the second half describing the mathematical and statistical contributions and areas of opportunity for future work. The Board has initiated work on the first three cross-disciplinary reports: spatial statistics and image processing, data fusion, and recent work in mathematical biology in the area of molecular genetics and evolution and mapping the human genome.

The Board has decided to supervise the development of a series of focused state-of-the-art reports in the mathematical sciences. These reports will be written primarily for the mathematical science community (graduate faculty and students, in particular) and will highlight areas of promising and intensive mathematical sciences research. The first report will be on probabilistic algorithms.

CATS sponsored a symposium at the National Academy of Sciences during November 1989 (National Statistics Month) to commemorate the Sesquicentennial of the American Statistical Association. The symposium, entitled "Statistics, A Guide to Assessing Societal Risk," was well

received by the 125 regional participants. CATS plans to produce proceedings from this symposium in 1990. Motivated by the national need to enhance state-of-the-art practice of statistical process and design control (SPDC), CATS has moved forward with plans for a substantial study and evaluation of quality control and productivity. Quality and productivity improvement is an issue affecting both national security and the competitiveness of American products in world markets. It is anticipated that the results of this study will have beneficial impact on the practice, teaching, and future research for SPDC, and thus contribute to the national quality and productivity improvement. CATS also is undertaking a study leading to the development of guidelines for evaluating statistical software. The current situation is bad, with scientists, economists, and planners relying heavily on the output of an increasing number of statistical software packages which have been shown to produce different and nonconforming results. One objective of this study is to identify and articulate a suitable scientific basis and performance objectives for statistical software.

The 1989 National Science and Technology Week Symposium was held in May and attended by over 200 participants. The topic, Number Theory, was presented by four distinguished mathematicians from across the country. The Board will also produce proceedings from this symposium in 1990. On October 27-28, 1989, the Annual Department Chairs' Colloquium was held in Virginia. The topic of the symposium was "Chairing the Mathematical Sciences Department of the 1990's." Over 200 department chairs and federal agency representatives attended.

In 1988, the ICEMAP agencies requested the Board on Mathematical Sciences to undertake the development of an update of the David Report. This update will include assessment over the subsequent five years of progress within the community and specifically on the recommendations of the original report, identification of new or changed factors affecting the mathematical sciences, description of programmatic and research opportunities, and recommendations. The update will tie together and rely upon a wide range of community work and initiatives, including other Board work such as the Research Trends, cross-disciplinary and focused reports, and the MS 2000 project. The original David Report is credited with giving rise to an 84 percent increase (in current dollars) in total funding in the mathematical sciences in the period 1985 - 1988. However, this progress fell far short of the goals recommended by the David Report to increase the numbers and output of and support for active research mathematical scientists. The Board was substantially involved in this critical update during 1989. The report is planned for publication and dissemination in the spring of 1990.

The character and scope of the Board on Mathematical Sciences has changed during its first three years of core funding. Beginning as a somewhat senatorial body representing university core mathematics, applied mathematics, and statistical science equally, it focused its initial energies on representing the science of mathematics at the National Research Council. Having done so well with scientific reports and symposia, the Board extended its scope scientifically to include

operations research and applications areas and now is exploring what its proper role should be in the policy arena and as a resource to ICEMAP. The Board is positioned to be the central representative of scientific and policy issues affecting mathematical sciences research and training in the science policy arena. The Army Research Office has agreed to provide partial core funding to the Board for the period 1989-1992.